Sub-decadal North Atlantic Oscillation Variability in Observations and the Kiel Climate Model

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1 The North Atlantic Oscillation

The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability in the North Atlantic sector (Hurrell et al. 2003). The corresponding NAO index describes the sea level pressure difference between the subtropical high and the subpolar low. This index exhibits variability on a wide range of timescales. The sub-decadal variability of the NAO is pronounced in observations and models (e.g., Deser and Blackmon 1993, Eden and Greatbatch 2003, Alvarez-Garcia et al. 2008), but the underlying mechanism is still under discussion.
Here we investigate the sub-decadal NAO mode using observations and a fully coupled general circulation model.

2 Model and experiments

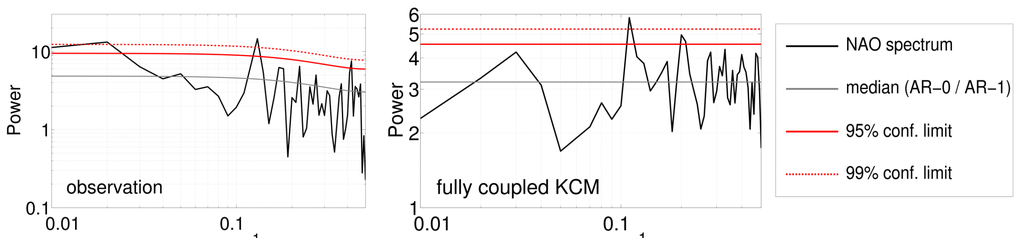
Kiel Climate Model (KCM) - Park et al. 2009
• atmosphere model: ECHAM5 [T31, L19]
• ocean sea-ice model: NEMO (OPA9-LIM2) [2° horiz., 31 vert. levels]

Experiment
• present-day control simulation
• analysis of 700 yrs (300 yrs spin-up period removed)

Winter (DJFM) means are used except for the annual averaging of the Atlantic Meridional Overturning Circulation (AMOC).

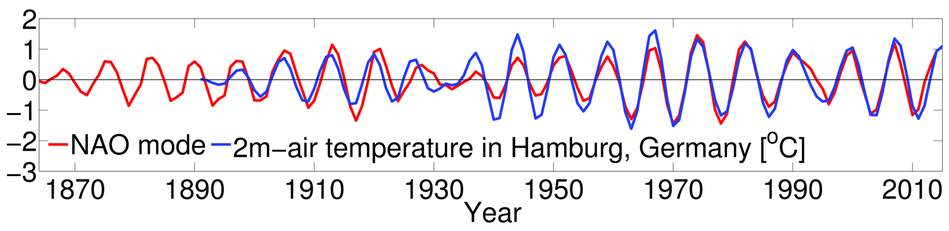
3 Sub-decadal variability

Pronounced sub-decadal variability in present in the observed (based on HadSLP2 1850-2014) and modelled NAO index power spectrum:



The sub-decadal mode is also identified through Singular Spectrum Analysis.

Reconstructions of the sub-decadal mode from observations:

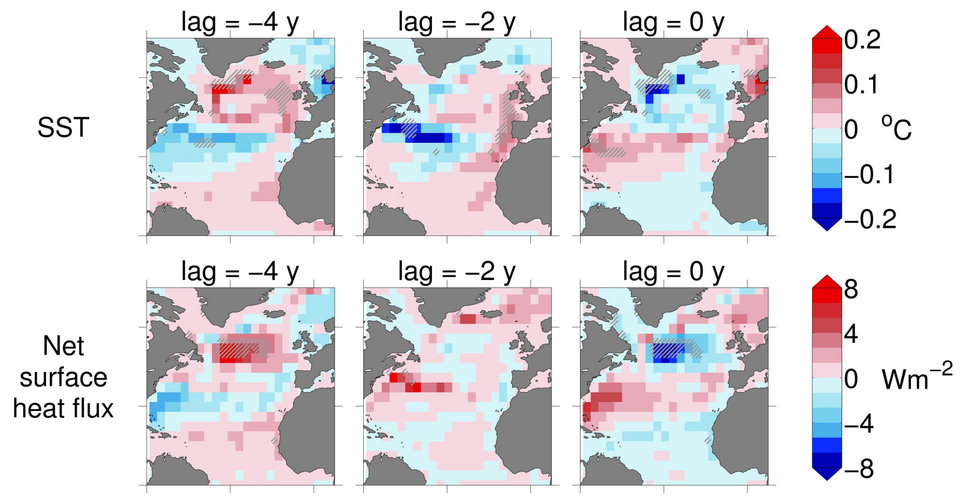


The sub-decadal mode explaines 18 % of the NAO variability in the observation and 4 % in the KCM (given a window length of 15 and 100 years, respectively).

4 Positive feedback

During the extreme phases of the NAO the net surface heat flux anomalies (from the atmosphere to the ocean) drive SST anomalies, but they damp them during the transition phase. Hence, the continuing surface cooling in the west of the North Atlantic during the transition phase must be caused by dynamical ocean processes that establish a positive feedback on the SST and the NAO.

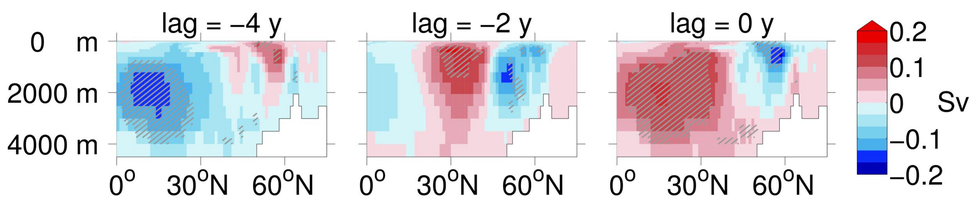
KCM regressions onto the sub-decadal NAO mode



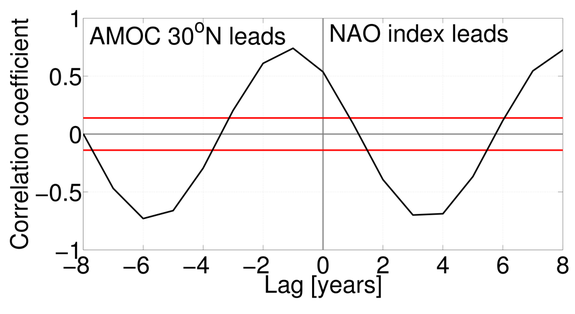
5 Delayed negative feedback

The dipolar heat flux anomaly of the preceding negative NAO phase causes a dipolar anomaly in the AMOC during the transition phase. This dipolar structure reverses the anomaly pattern of SST by modulating the meridional heat transport and causes a phase change of the NAO.

KCM AMOC regressions onto the sub-decadal NAO mode



Just like the NAO index also the AMOC index at 30°N exhibits a sub-decadal mode. The modes of both variables are strongly lag-correlated which indicates that they are part of the same physical mode.



6 Conclusions

Three elements are critical for the sub-decadal mode of the NAO:

1) a positive feedback through ocean dynamics (wind-induced changes modulate the upper ocean circulation / heat advection)
2) a delayed negative feedback through an adjustment of the AMOC that sets the timescale of this mode
3) large-scale ocean-atmosphere coupling with SST feeding back on the NAO

Ocean-atmosphere coupling:

The sub-decadal mode is not reproduced when the KCM is run with a slab-ocean model instead of a dynamical ocean model or when using only the atmopheric component.

Further, when forcing the atmosphere-only model with the SST anomalies linked to the positive NAO index, an anomalous sea level pressure pattern is retained that reflects the positive NAO phase.

These findings support that the sub-decadal NAO mode is produced by ocean-atmosphere coupling.

Reintges, A., M. Latif, W. Park (2016): Sub-Decadal North Atlantic Oscillation variability in observations and the Kiel Climate Model; Climate Dynamics

References

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Acknowledgements

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